Space Shuttle
Technology Summary

Main Engine Advanced Health Management System

At launch, the Space Shuttle's Main Engines operate at greater extremes of temperature and pressure than any other machine, placing the entire system under immense stress. NASA is confident that an upcoming improvement in those engines will further enhance safety, reliability and overall performance of the Space Shuttle. The enhancement is a high-tech system that couples vibration sensors with advanced digital signal processing and upgraded computing technology. The system will monitor the operation of the Shuttle's Main Engines and will "see" a problem a fraction of a second before it could do harm. Called the Advanced Health Management System, it is one of the concepts being developed by NASA's Marshall Space Flight Center in Huntsville, Alabama.

The Advanced Health Management System has two primary elements – the Advanced Space Shuttle Main Engine Controller and the Health Management Computer. This system, which will monitor the Main Engine from start to cut-off, will be able to detect and track a flaw in the Engine's performance in a split second. The system will analyze Engine data and, should a significant health risk arise, will mitigate that risk by correcting propellant mixture ratio, throttling the Engine down to a safer power level or safely shutting down the Engine.

The technology will be introduced in two phases. The first phase is the development and production of the Advanced Main Engine Controller - set to fly in 2004. It will operate in conjunction with existing Engine sensors, valves, and actuators to provide a self-contained system for control, data gathering and health management of the Shuttle's Main Engines. The existing controller is being modified to include advanced digital signal processing technology, additional radiation-hardened memory, external communications ports — for communication with the Health Management Computer — and new software. These new features will enable the Advanced Main Engine Controller to detect vibration anomalies in the Main Engine's high-pressure hydrogen and oxygen turbopumps that are symptomatic of a potential failure. If these vibration anomalies exceed safe limits, the "unhealthy" Engine will be safely shut down.

The second phase of the Advanced Health Management System is the development and production of a new Health Management Computer. This computer consists of two subsystems that work together to provide additional monitoring of the performance and health of the Shuttle's Main Engines.

The first of these subsystems – the Advanced Real Time Vibration Monitoring System – provides greater insight into turbopump vibration anomalies by comparing real-time operational Engine data to known failure scenarios. This allows implementation of pre-established contingency actions such as throttling, shutdown or continued operation.

The second subsystem – the Linear Engine Model – was originally developed and utilized as a post-test and post-flight diagnostic tool to identify and quantify engine performance anomalies. The flight version of the Linear Engine Model continuously performs a real time comparison of observed slices of Main Engine performance data with pre-determined data to assess Engine health. Comparison discrepancies or "symptoms" are then matched to known performance failure indications, allowing the system to "diagnose" the Main Engine performance anomaly. Two key features of the Linear Engine Model are its ability to diagnose multiple, simultaneous failures and its ability to provide a confidence score in relationship to the anomalies.

When implemented, the Advanced Main Engine Controller, coupled with the Health Management Computer system, will significantly improve Space Shuttle flight safety and reliability.